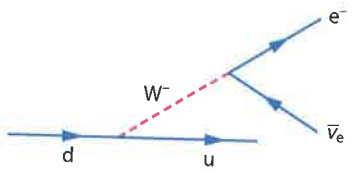
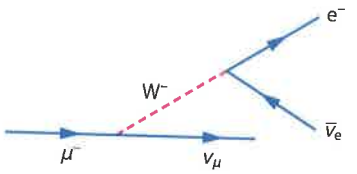
43 **a** $d \rightarrow u + e^- + \bar{\nu}_e$

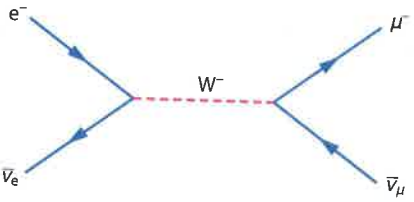
b



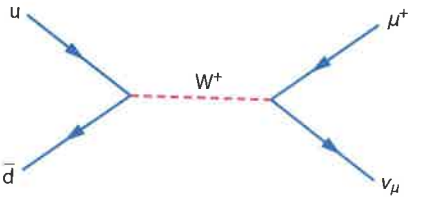
44 **a**



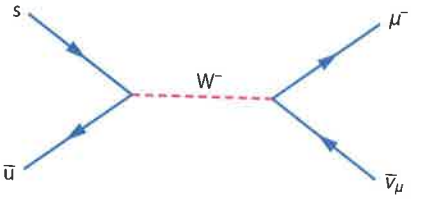
b



c

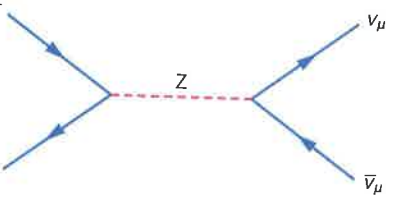


d

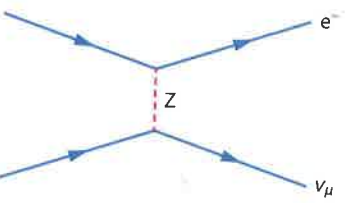


45 $W^- \rightarrow u + d (\rightarrow \text{hadrons}); W^- \rightarrow e^- + \bar{\nu}_e;$ $W^- \rightarrow \mu^- + \bar{\nu}_\mu$

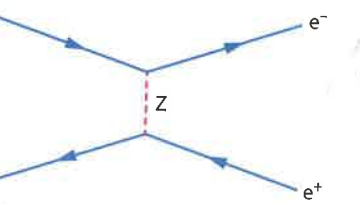
46 **a**



b



c



Topic 8 Energy production

8.1 Energy sources

1 **b** $3.7 \times 10^5 \text{ J m}^{-3}$

2 **a** $5.0 \times 10^8 \text{ J}$

b $1.6 \times 10^{16} \text{ J}$

3 **a** 2.5%

4 **a** $1.0 \times 10^9 \text{ W}$

b $2.4 \times 10^9 \text{ W}$

c $1.2 \times 10^5 \text{ kg s}^{-1}$

5 6.3 km

6 $7.2 \times 10^6 \text{ kg day}^{-1}$

8 **a** 185 MeV or $2.96 \times 10^{-11} \text{ J}$

b $6.77 \times 10^{18} \text{ s}^{-1}$

9 **a** $8.20 \times 10^{13} \text{ J kg}^{-1}$

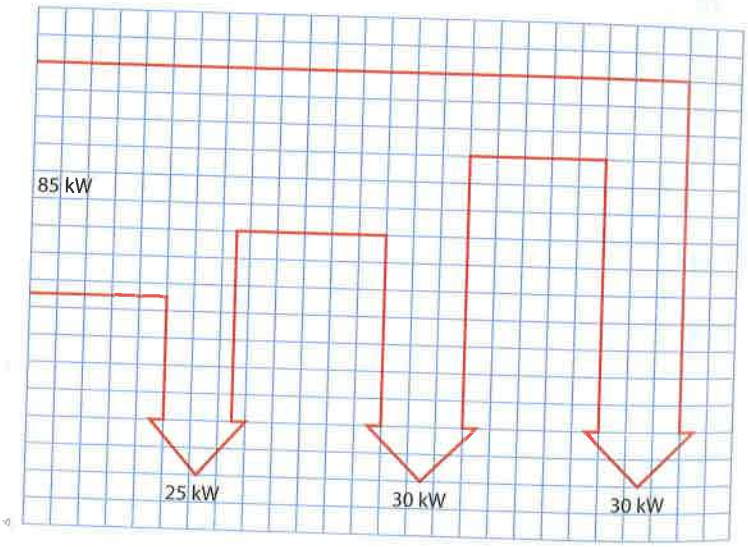
b $2.7 \times 10^6 \text{ kg}$

10 **a** $3.9 \times 10^{19} \text{ s}^{-1}$

b $1.5 \times 10^{-5} \text{ kg s}^{-1}$

13 **a** 12.2 (so about 12) m^2

b



14 6.5 m^2

15 3.6 h

16 **a** 338 K

b 800 W

c 0.40 (40%)

17 $3.6 \times 10^{11} \text{ J}$

18 **a** **i** increases by a factor of 4

ii increases by a factor of 8

iii increases by a factor of 32

20 2.0 kW

21 4.3 m

22 $2.0 \times 10^8 \text{ W}$

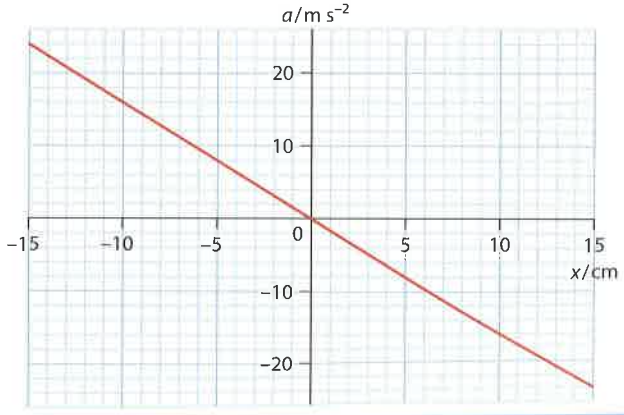
8.2 Thermal energy transfer

26 **a** yes
b no
28 81
29 **c** 1.8
30 **b** 0.6
31 278 K
32 **a** $T \propto \frac{1}{\sqrt{d}}$
b 1.4 K
33 **b** 2.4 W m^{-2}
35 **a** $(4.5 \pm 0.1) \times 10^2$ K
38 **b** 0.29
c 250 W m^{-2}
d 258 K
39 **d ii** 242 K
44 approximately 2 K increase in temperature

Topic 9 Wave phenomena(HL)

9.1 Simple harmonic motion

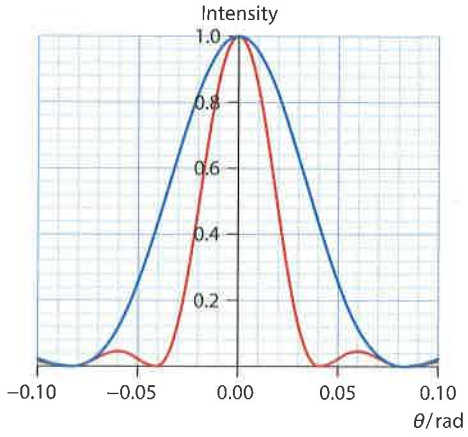
2 **a** $-\frac{\pi}{2}$
3 **a** 5.0 mm
b −3.7 mm
c 0.99 s
d ±4.0 mm
4 **a** $8.0\cos(28\pi t)$
b $y = -4.7$ cm, $v = -5.7$ m s^{-1}, $a = 3.6 \times 10^2$ m s^{-2}
5 $v = 14$ m s^{-1}; $a = 4.2 \times 10^4$ m s^{-2}
6 **a** 520 Hz
c 6.0 mm
d 1.0 m
e 4.2 mm
7 **a** 0.51 cm
b twice the amplitude
c $-0.25\sin(5\pi t)$
8



9 **b** 1.6 s
c 0.40 m s^{-1}
d 0.24 N
e 0.012 J
10 **a** 9.94 mm
b 2.35 N
11 **a** mass $= M(\frac{x}{R})^3$
b force $= GMm(\frac{x^3}{R})$
d period $= 2\pi\sqrt{\frac{R^3}{GM}}$
e 85 minutes
f same
12 **a** 0.57 s
13 **a** 27.0 m
b 34.2 m s^{-2}
c 3.28 s
d 17.7 m

9.2 Single-slit diffraction

14 38.2°
15 20 cm
16 **a** $\lambda \approx 24b$
b **i** New curve in blue;
ii Same as original (shown in red)



9.3 Interference

17 8.5 mm
19 $n = 3$
20 **a** 6.46×10^{-7} m
21 **a** 2.92λ
22 **a** 0.0°; 13.89°; 28.69°; 46.05°; 73.74°
b $n = 4$

15 **a** 11.8 N at 75.4° below the horizontal
b 5.1×10^{5} V
c 5.1×10^{-4} J

16 **a** 0.8 μC (smaller sphere) and 1.2 μC
b 6.37×10^{-6} C m^{-2} (smaller sphere) and 4.24×10^{-6} C m^{-2}
c 7.2×10^{5} N C^{-1} (smaller sphere) and 4.8×10^{5} N C^{-1}

18 **a** 0.30×10^{-3} J
b -0.30×10^{-3} J
c -0.60×10^{-3} J

19 **a** −7.19 V
b -1.6×10^{-19} C

20 **a** $\frac{qa}{2\pi\varepsilon_0(d^2 + a^2)^{3/2}}$ or $\frac{2kqa}{(d^2 + a^2)^{3/2}}$ vertically down
b $\frac{qd}{2\pi\varepsilon_0(d^2 + a^2)^{3/2}}$ or $\frac{2kqd}{(d^2 + a^2)^{3/2}}$ horizontally to the left

21 $W = \frac{3ke^2}{r} = 1.4 \times 10^{-18}$ J

10.2 Fields at work

22 **a** 7.6×10^{3} m s^{-1}
b 95 minutes

24 **a** about 35 870 km (i.e. about 42 250 km from the Earth's centre)

25 Orbit 1 is not possible, orbit 2 is.

26 The normal reaction force from the spacecraft floor is zero.

27 **a** The total energy is $E = -\frac{GMm}{4R}$, i.e. negative.
b $r = 4R$
c $v = \sqrt{\frac{3GM}{2R}}$

28 -5.29×10^{33} J

29 **a** B
b A
c A

30 **a** Its total energy is negative.
b $\frac{5R}{2}$

31 positive because the total energy increases

34 **c** about 4

35 **c** 1.1×10^{6} m

36 **a** $F = \frac{GM^2}{4R^2}$
c $T = 7.8h$
f **ii** 3.9×10^{-9} J yr^{-1}
g 2.6×10^{8} yr

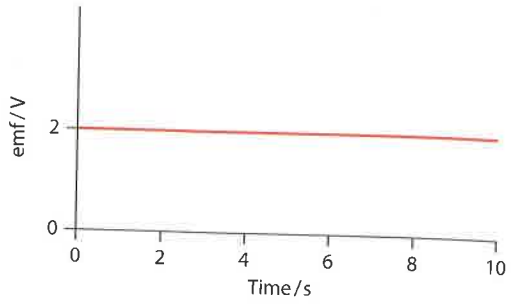
37 **d** $\frac{q^2}{16\pi\varepsilon_0 r}$ or $\frac{kq^2}{4r}$

38 **b** 1.4×10^{-16} s
c 1.7×10^{-18} J

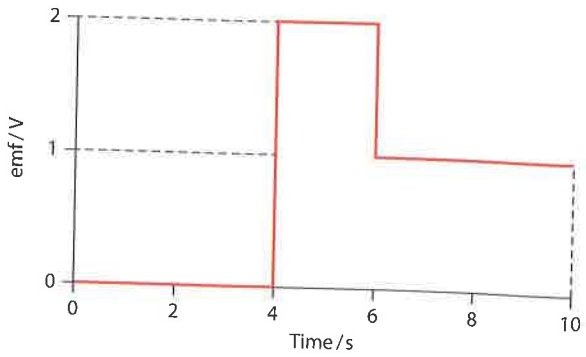
Topic 11 Electromagnetic induction (HL)

11.1 Electromagnetic induction

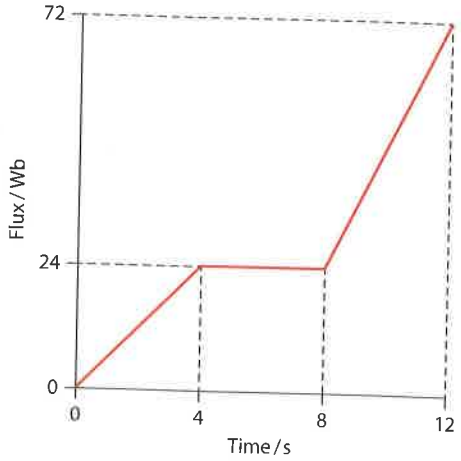
1



2



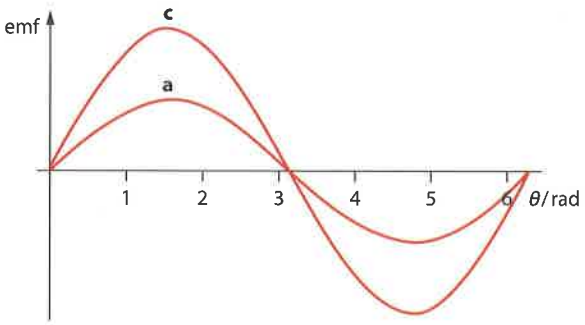
3 **a**



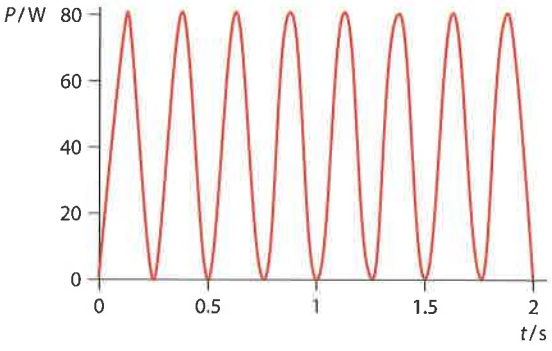
4 counter-clockwise
5 **a** clockwise, then zero, then counter-clockwise
b counter-clockwise, then zero, then clockwise
6 **a** counter-clockwise, then zero, then clockwise
b clockwise, then zero, then counter-clockwise
7 **a** force is upward
b force is upward
8 right end is positive
9 **a** clockwise
b counter-clockwise
10 28 mV

11.2 Transmission of power

14 **b** The graph in question 14 remains unchanged.
a, c The emf has double the amplitude at the high speed but the dependence on angle is otherwise the same. Note that no numbers have been put on the emf axis as we do not know the rate of rotation.



15 **a** 2 A
b 5 V
c 1 s
d



16 **a** 88 V; 50 Hz
b 10.5 A
17 **a** 23.4%
b 15%
18 0.0825 T
19 4.9×10^4 V
20 **a** 30%
b 1.2%
21 410 W

11.3 Capacitance

22 About 1100 km^2
23 6.6 nC
24 0.18 A
25 **a** 180 mC
b 0.81 J
c 16 W
26 **a** 360 μF
b 7.2×10^{-4} C and 1.4×10^{-3} C
c 2.2×10^{-3} J and 4.3×10^{-3} J
27 **a** 80 μF
b 4.8×10^{-4} C each
c 9.6×10^{-4} J and 4.8×10^{-4} J
28 **a** The 24 pF has charge 1.5×10^{-10} C and the other 4.5×10^{-10} C.
b 5.4×10^{-9} J
29 **a** 18 J
b 6.0 s if we assume that the lamp will be lit for a time equal to the time constant
31 **a** 0.70 mC
b 1.8 mA
c 27 V
32 **a** just over 2 s (2.1 s)
b 42 kΩ
33 **a** 1.5 ms
b 80 μA
34 **a** 1.6 μA
b 13 μJ
c 13 μJ

Topic 12 Quantum and nuclear physics (HL)

12.1 The interaction of matter with radiation

1 **b** 7.24×10^{14} Hz
2 **b** 0.671 V
3 **b** 1.6×10^{-4} A
c 0.20 eV
d 2.1 eV
e 3.2×10^{-4} A

4 **b** **ii** 2.7×10^{-7} m

5 **b** 3.90 eV

6 **a** 16 min

7 **a** **i** 5.0×10^{14} Hz

ii 2.08 eV

b 1.25 eV

c the graph is parallel to the original graph

8 11.5 eV or 1.3 eV

9 **b** $i = 1.5\ \text{W m}^{-2}$

c $f = 3.0 \times 10^{18}\ \text{m}^{-2}\,\text{s}^{-1}$

d There are fewer photons incident on the surface per second and so fewer electrons are emitted.

e One assumption is that, at both wavelengths, the same percentage of photons incident on the surface cause emission of electrons.

10 **b** **i** no excitation

ii 4

iii 6

11 **b** 1.51 eV

12 **a** 9.1×10^{-8}

b $2.2 \times 10^{6}\ \text{m s}^{-1}$

13 **a** 2.65×10^{-34} m

14 **b** $1.1 \times 10^{3}\ \text{m s}^{-1}$

15 **b** $\sqrt{8} \approx 2.83$

c 5.4×10^{-11} m

16 **a** 2.0×10^{-15} m

b 6.6×10^{-10} m

18 **b** 5.5×10^{-10} m

20 $\theta \approx 10^{-35}$ rad

22 **a** top diagram

b bottom diagram

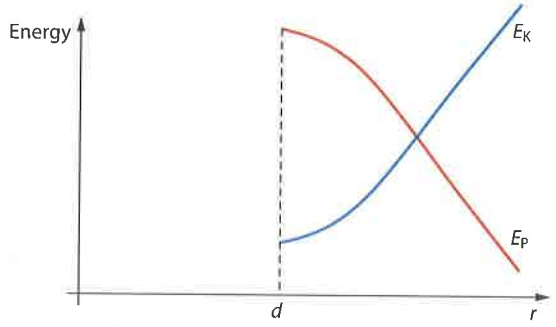
23 **a** 2×10^{-15} m, i.e. of order 10^{-15} m

b of order 10^{6} MeV

12.2 Nuclear physics

24 $3.6 \times 10^{7}\ \text{m s}^{-1}$

25



28 **b** $^{226}_{88}\text{Ra} \rightarrow {}^{226}_{88}\text{Ra} + {}^{0}_{0}\gamma$

c 1.83×10^{-11} m

30 I and IV are beta plus decays, II is a gamma decay and III is beta minus decay

31 **a** $0.231\ \text{s}^{-1}$

b **i** 4.78×10^{21}

ii 3.79×10^{21}

iii 3.01×10^{21}

32 **a** 0.5

b 0.875

c 0.5

33 3.66×10^{10} Bq

34 1.10×10^{6} Bq

35 4.20×10^{11}

36 3.8×10^{9} yr

37 4.11×10^{9} yr

38 **a** 0.75

b 0.95

c 1.50